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## PLANNING AND ENGINEERING OF U.S. AIR FORCE BASES

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AIR TRANSPORT DIVISION

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# PLANNING AND ENGINEERING OF U.S. AIR FORCE BASES

Lee B. Washbourne[1]

This paper is divided roughly into three parts; first, the evolution of our present-day airfield design criteria; second, the operational phases of air base development including site selection, master planning, programming, and design. And third, future air base concepts.

The airplane requires a base, as a bird requires a nest. Early bases were no more than cow-pastures or open fields, from which a few crude airplanes could take off and land. The air base was a military post or camp, with a small flying field nearby. Later, when the military planners found that these airplanes, though unreliable, could be used as flying gun platforms, long-range observation posts, long-range artillery and cargo and personnel carriers, the number of planes kept on one field was increased. Regular military units, squadrons and groups, were formed; people had to be housed, fed and trained; and the airplanes had to be maintained. Thus began the evolution of today's modern military air base. For years no particular thought was then given to strategic location, air defense, or to paved runways. Then in the late 1930's—faster, heavier and longer-range aircraft began emerging from our factories. The B-17 bomber amazed and delighted the U. S. Army Air Corps; and the DC-3 (or C-47) made its debut as a fast, safe commercial transport. By then some military and civilian planners, with more foresight than most of us, decided that 1st—the airplane was here to stay; 2nd—the longer it stayed the bigger it would get; and 3rd—the bigger it got the more airport facilities it would require. Based upon this long range estimate of the situation, these individuals persuaded their governments—local, state and federal, to acquire suitable tracts of land for airfield purposes, to be developed over a long period of time. Several of our present permanent Air Force bases were constructed during this period.

During World War II, the normal development of aircraft and flying facilities was accelerated tremendously. Speed of construction was the watchword in those days. Many tracts of land for bases were acquired in one day and construction started the next. Little thought was given to expansibility, dust control, maintenance and operation costs, livability or community participation. Bases were constructed to absolute minimum standards. Runways were short and of inadequate strength and lacking in proper drainage. Buildings were of Theater of Operations type—slab on grade, tar-paper-covered frame, heated with pot-bellied stoves, poorly lighted. Water lines, when provided, were uncoated steel or even wood pipe laid in shallow trenches. In general, these bases were capable of performing their immediate mission and did so at minimum initial investment and minimum construction time. They were laid out using sets of standard plans, block patterns and requirements that had been set up by the Army for all mobilization camps. Practically none of these bases were properly planned in the long-range sense for multi-purpose use. Expansion or mission changes were provided for during the War by crowding and doubling up. Mess halls operated in shifts. Bunks were double-decked.

1. Maj. Gen., U. S. Air Force, Director of Installations.

Floor space in barracks was rationed to less than 48 sq ft per individual. Aircraft that couldn't be parked on the paved parking aprons were parked on the grass. Water was a critical item at many bases. Electricity was rationed by lowering the wattage in light bulbs. Naturally at the end of the war these bases were the first to be closed, declared surplus and disposed of, usually to the nearest municipality.

During the latter part of World War II, jet-propelled military aircraft were in the design and development stages. The early jets, F-80, Shooting Stars appeared very shortly after the war. Only bases originally constructed for the B-29's were capable of handling these new jet aircraft. These bases had to be used for the jets until runway extension had been provided at fighter bases and training stations. Overnight there developed a trend in aircraft power plants to jet engines and away from piston types. Today, in air base planning, the Air Force is developing criteria not only to meet today's transitory requirements, but also to meet the new developments we can foresee in aircraft, guided missiles and atomic power. We cannot now design a "Buck Rogers" space port—although I'm sure we will be doing it some day—until sufficient data and requirements are forthcoming from the aircraft industry. The air base of tomorrow will still be a result of evolution—one change at a time—rather than a spectacular revolutionary jump from today's jets into the spaceship era. Air power is still in its infancy and air base development must parallel the development of the aircraft, weapons, and strategy of war for which the base is built.

The Air Force today is in another expansion period similar to that in 1940-41. New bases are being built; old bases being remodeled; surplus bases are being re-acquired. This expansion is not as hurried as the '40-41 expansion, however, and every effort is being made to eliminate the mistakes made in air base planning during World War II. I will mention specific problems and examples which have arisen:

(a) Runway lengths:—When a new aircraft is developed, tested, and delivered to the Service, the ultimate runway length requirement may be much more than originally specified to the aircraft manufacturers. The aeronautical engineers have designed and produced an aircraft to meet certain specifications as to range, load carrying capacity, speed etc. However, operational people will invariably throw on a few extra pounds of ammunition, guns, fuel, armor plate—turrets, radar and radio equipment etc., until they have the plane so heavily loaded that its pay load is reduced considerably. So the next step is to increase the allowable gross weight, as in the case of the old B-24 which was designed to fly at a gross weight of 56,000 pounds. When they finally got the B-24's fully loaded for combat missions, the gross weight was over 70,000 pounds—a 25% increase. Increased allowable gross weights are accompanied by a corresponding decrease in take-off performance, so that the additional load increases the required runway length. Runway length requirement for a particular type airplane is calculated by determining the ground run on take-off of the aircraft at maximum gross weight at the pressure altitude of the base and at the average temperature of the hottest month, times a 1.75 safety factor. For training bases, the safety factor is increased to two. If the allowable gross load of the airplane in question is later increased, the runway will require an extension. Today we have a number of runways over 12,000 feet long and some 14,000 feet long. In the foreseeable future, it is possible that longer runways will be required. New concepts of "zero launching" of guided missiles may soon eliminate the need for such gigantic runways, but for the present we must figure on accommodating aircraft presently under development and others like them.

(b) Pavement types:—Naturally, in addition to increased runway lengths, increased pavement strength must be provided to withstand the heavy loads and high tire pressures. The highways of today capable of withstanding the continual pounding of the heaviest trucks and buses are weak compared to the strength that must be built into aircraft traffic surfaces. These surfaces include the runways, taxiways, parking aprons and hangar floors. Some of our fighter type aircraft today have tire pressures of 200 pounds per square inch. These high pressure tires rut the surfaces of flexible type pavements which are not backed up by substantial and highly compacted base courses. The hot blasts from jet engine exhausts plus some spilled jet fuel can cause asphaltic concrete pavement to soften and deteriorate. Particles of broken pavement are extremely dangerous in jet operation, not only from the standpoint of ruining tires but because they often are sucked into the forward end of the jet engines causing considerable damage to the high-speed turbine blades. Screens were installed in the front of jet engines to protect them against damage from foreign matter but the screens proved more hazardous than useful. Under the freezing temperatures encountered at high altitudes, moisture in the air formed ice on the screens and choked off the air to the engines. A whole flight of aircraft crashed due to this cause.

As aircraft get larger they require more square yards of airfield traffic surface. The runway must be wider as well as longer. Today's criterion is 300 foot wide runways for heavy bombers. Taxiways must be wider and the shoulders fully stabilized to protect them against jet blast from outboard jet pods and sustain the weight of the outriggers used in conjunction with the bicycle-type landing gear on the B-47 and B-52. Parking aprons must be large enough to park and maneuver the aircraft in and out of parking position. The parking of jet aircraft is a problem. If one plane is parked too close to the tail of another, the heat from the engine of the forward plane may melt or mar the plexiglass canopy of the rear plane. To prevent this from happening, more distance is allowed between parked planes, and the planes are parked at a 45 degree angle to increase nose to tail distance. With heavy duty pavement costing in the neighborhood of twelve dollars per square yard in the continental United States, the cost of providing only the minimum runways, taxiways and parking aprons for a wing of medium or heavy bombers is very great.

(c) Approach Zones and Zoning:—Larger and faster aircraft not only need more pavement upon which to operate, but also the pavement must be placed so as to give more clearance from fixed or moveable objects. Today's minimum clearance for runways is 750 feet either side of the center line and 1,000 feet at the ends. However, for planning new bases, we are shooting for a 1,000 foot lateral clearance and 1,500 foot end clearance. With the parking apron 1,000 feet wide or more and a minimum 125 foot clearance from the back edge of the apron to any building, it can be seen that the airfield is already a mile wide not counting any building area or without provision for a cross-wind runway.

A 14,000 foot runway cannot be used effectively to its full length, unless all obstacles are removed from the approach zones at the runway ends. The presence of a 1,000-foot television tower a mile or so off the end of the runway would be a tremendous hazard to air navigation. Objects which protrude above a glide angle of 1 on 50 are considered hazards and removed. Today, the approach zones to runways extend 25,000 feet beyond the runway ends. This zone fans outward and upward from a line 1,000 feet beyond the runway end to a height of 200 feet and a width of 4,000 feet at a distance of about 2 miles. At this distance, the zone continues horizontal at a constant width of 4,000 feet

to a distance of 25,000. In addition to the height limitations in the approach zone, a circle is drawn 50,000 feet in radius centered on the airfield. If at all possible through local zoning ordinances, we attempt to limit the height of any and all objects within this 10 mile circle to 500 feet above average airfield elevation. Many of today's air bases fail to meet all these clearance criteria, but in the case of a new air base being constructed on a virgin site, every attempt is made to obtain all the clearance and zoning criteria. Without this protection, the usefulness of the air base is seriously reduced and future capabilities for expansion are practically eliminated.

(d) Navigation Aids:—The aircraft of today and those of tomorrow are not only bigger and heavier, but also much more complicated. In order to navigate a 500-mile-an-hour aircraft from one point to another, the navigator must work over 3 times as fast as he did in a 150-mile-per-hour plane. The extreme high altitudes make visual reference to the ground practically impossible. In a plane like the B-36, the navigator has plenty of help in the way of manpower because the crew has 14 to 16 men in it. But the super-fast B-47 carries a crew of only 3 men, and the fighter planes are almost all single seaters. These navigation requirements complicate the air-base planners' problem in two ways; (1) many electronic and radio navigational aids must be added to the base plan, and (2) a first-class electronics maintenance building must be provided to maintain the airborne portions of the radar sets. Some of the aids to navigation in current use are ground-controlled approach systems, instrument landing systems, VHF direction finders, UHF direction finders, radio beacons, radio ranges, marker beacons, airfield surveillance radar, ground-controlled intercept radar and others, in addition to the standard traffic control radio equipment. All this equipment must be sited so as not to interfere with each other and not pick up interference from natural or man-made objects. The layout of the airfield and the proper navigational aids are all designed to get an approaching aircraft safely on the ground in the least possible time in any weather. Although a jet aircraft is very fast and can cover tremendous distances at high altitudes, it does not have very much endurance at low altitudes. Whereas an air-liner can circle the field in bad weather for hours waiting its turn to land, a jet would run out of fuel if it had to perform many holding maneuvers. Therefore, the best electronics equipment is used to aid its speedy descent and landing, and keen operational procedures have been developed to reduce holding times to the minimum and expedite landing clearances for jet aircraft.

(e) Refueling Systems:—In addition to the runway, probably the next most important part of an air base is the fuel storage and dispensing system. The standard method of handling aviation gasoline during World War II was to store it in large quantities in a bulk storage form some place on the base, haul it in tank trucks filled at a truck fill stand to the airplane and pump it in. The smaller aircraft could be serviced with fuel quickly and even a B-17 would require only about 1/2 a tank truck of fuel at the most. At some bases where roads were good, one tractor truck could haul two refueling trailers.

But today's aircraft are practically "flying gas-tanks." They "drink up" fuel at a much higher rate than was ever dreamed of ten years ago. The B-36 can hold 20- 25,000 gallons of fuel. Even the jet fighters haul more fuel than the C-47. In order to supply fuel for this "breed" of aircraft, using the old method, we need about one truck per aircraft. Heavy bombers would each require four to six tank trucks. Additionally, the rate of fuel transfer is so slow that it would take all night to re-fuel a B-36 for a flight the next morning. The answer to our problem has been to bring the fuel directly to the aircraft

through pipe lines, pumps, filters, meters, hydrants and short lengths of hose. Requirements call for a refueling rate of 600 gallons per minute delivered to the aircraft. Provision is also made for de-fueling aircraft, to reduce the static load on the wings and tires, and to remove from the aircraft fuel that may have warmed up considerably in the sun. The fuel removed from the planes is pumped back to operating storage tanks and fresh fuel which has been cooling in an underground tank is serviced into the aircraft immediately prior to a flight to minimize "boil off." The hydrant refueling systems presently in use have justified their initial cost in several ways and are the only method we have now that is operationally capable of meeting the high speed fueling and de-fueling requirements.

(f) Maintenance Facilities:—The Air Force demands safe flying, and to fly safely an aircraft must be properly maintained. A large part of the maintenance is done outdoors, but some of it must be performed in hangars. Very few World War II hangars are large enough to accommodate today's large bomber and cargo aircraft. They will handle only fighter planes, trainers and obsolescent administrative planes. Therefore, a new set of designs was developed for maintenance hangars. It takes a huge hangar to swallow up 2 or 3 B-36's, with their 230-foot wing span and 162-foot overall length, not to mention the 5-story-high tail. Two standard hangars are now in use. One is the enclosed maintenance hangar either double-cantilever or concrete arch; the other is the nose-hangar. The latter shelter only the nose and wings of the aircraft, leaving the tail exposed. Doors with semi-circular notches (doughnuts) in them fit tightly around the fuselage aft of the wings and close out the outside air. These hangars were not designed especially for one type of aircraft either; they are truly multi-purpose and will hold one B-36 or B-52, or two B-29's or B-47's. In siting the hangars on the air base, the maximum flexibility is maintained, so that any type aircraft can have ingress or egress. Older Air Force bases have hangars which are too small for the present day aircraft. On them, new hangars have been provided and the old ones are now being used for automotive maintenance, base supply, warehousing, shops, gymnasiums, etc.

(g) Housing:—Today's air base is planned not only for the aircraft that fly from it, but also as a home for the crews that operate and maintain these aircraft. The military man who devotes his life to the Air Force deserves as good a home as his civilian brother. He insists on good housing above good pay. Unless we provide adequate dormitories for single airmen and officers, and family quarters for the married personnel, these highly-trained valuable men leave the military service as soon as their current tours are completed. To provide adequate quarters, new dormitories and bachelor officers quarters have been designed to provide comfort, privacy and safety. In addition to government constructed family quarters, Wherry-Act houses have been built by private enterprise on government land. Occupancy is guaranteed by the government. Rental scales on these homes is set by agreement. This program has been about the only source of family housing for the military services.

(h) Noise Levels:—The balance of the base has not been radically changed due to the switch over from conventional to jet aircraft. There is one exception: the redesign of plans to minimize noise levels in administrative and housing areas. As you know, conventional aircraft engines produce considerable noise, but the new jet engines equipped with afterburners for additional thrust generate intolerable sound levels. The sound level is so high that it is not only a nuisance, but can be painful and even injurious to health if the human

body is exposed to it over prolonged periods. To achieve an acceptably low sound level in such areas of the base as office, living and hospital areas, we now locate these facilities a minimum of 1,600 feet back from any aircraft operational areas. To stay on the "right side" of our civilian friends in communities neighboring on our bases, we have in several instances realigned the direction of the principal runway so that the aircraft flight patterns would not pass over or near populated areas. In addition, operational procedures have been worked out so that traffic pattern altitudes are maintained at a minimum of 1,500 feet above the ground, and located in such a manner that the minimum flight over populated areas occurs.

(i) Landscape Architecture:—Further advance in base design and master planning has shown that, for the same amount of construction money, our bases can be built in a pleasing and interesting pattern rather than with the old monotonous row-on-row of barracks and other buildings laid out in a gridiron patterns of streets. By utilizing the super-block principle, many little-traveled streets have been eliminated. More space has been allotted to buildings, giving more light and air to the occupants. By development of a pleasing color scheme for exterior painting, the drab building exteriors have been transformed from olive green or so-called "Army yellow" to an interesting and eye-pleasing array of colors. Proper planning and site location of structures also dictate that the topography of the terrain be used to maximum advantage. By eliminating the many short, straight roads found in a gridiron pattern, we are able to take excellent advantage of natural topography both by following the contours in road and utilities planning and by siting buildings so that a minimum of costly earth-moving is necessary. Proper planning can reduce large cuts and fills to the absolute minimum consistent with sound engineering design of roads and utilities.

(k) Community Centers:—A special item of interest to include at this point is the new Air Force concept of the community center. Although not new to civilian planners, it had not previously been used to advantage in air base planning. Today, the community center is a planned area similar to a modern shopping center in which all the service functions are located. It includes, in addition to automobile parking and vehicular and pedestrian circulation, such services as post exchange, Red Cross, commissary, gasoline service station, theatre, library, chapel, service club, nursery and others. A development such as this is pleasing to the eye, functional, and time-saving for the Air Force people who use these facilities; certainly a step forward in making the base a better place on which to live.

(l) Rehabilitation:—The changes I have just covered—in runways and clearances, operational facilities and support facilities due to development of new aircraft, new operational and planning concepts, cannot be implemented immediately on all Air Force bases. We must utilize and modify as best we can those bases which have been in existence a number of years. It is generally much cheaper to extend a runway at a completed base to provide for new aircraft than it is to start all over from scratch and build a new base. Another hurdle also stands in the way of new construction and that is the fact that a number of World War II bases are still in existence and can be rehabilitated and re-acquired at much less expense than construction of an entirely new base. Going back over the list of bases given up after the war, however, reveals that only a very small percentage of them are adequate to meet future Air Force requirements. Limitation of land due to terrain such as rivers, mountains, etc., and due to construction of housing developments that extend right up to the base boundary lines in many cases, precludes any economical

expansion of these bases. Also the strategic location, which is so much more important today than in World War II, many times limits the proper location of a base to a region in which no World War II bases are located. Another factor in re-acquiring bases turned loose 7 or 8 years ago is the present use to which the municipal owners have put the base. Almost all air bases which were released to municipalities were released under the condition that the bases would continue to be used as airport property, that is, not plowed up for farm land or developed as real estate subdivisions. In honoring this clause, some cities have developed their airports into very thriving and profitable businesses. The political implications involved in recapture of these airfields for the Federal Government are tremendous. Not only does it involve relocation cost for all the businesses on the base, but also the purchase of the city's interest in any improvements made to the property while under their jurisdiction. Many times it works a decided hardship on a city to have their airport recaptured. It means not only a loss of city revenue but also a reduction in the transportation network upon which the city has come to depend. Some cities are very reluctant to give up their airports, or even to share them. They maintain that mixing civilian and military aircraft traffic at one base is hazardous. So the problem of air base selection is not so simple. Actually, today we have practically exhausted the usable recapturable civilian airfields. At this point then further Air Force expansion must be based on acquisition of virgin tracts of land for development of new air bases.

To summarize briefly then, the thinking that goes into today's air base has been developed over a number of years and is made up of volumes of criteria and policy. These criteria and policies must be used as guides by air base planners. They cannot possibly fit all circumstances that arise at each individual base. Therefore, all our regulations and directives must be tempered with plenty of good common sense.

I will now discuss the operational phase of air base development including the site selection, master planning, programming, design and construction stages.

(a) Site Selection:—Site selection, in addition to being a tough engineering problem, is also a sensitive political and public relations affair. I will touch on the engineering aspects first and then on the political angles as a matter of interest. Today's multi-purpose air base properly laid out and planned for 100% expansibility will cover a minimum of 3,500 acres of land. The maximum acreage may be 4 times this amount. Runways of 15,000 feet by 300 feet cannot be built in mountainous terrain. In fact, the longer the required runway, the fewer are the sites available to construct it. In Texas for instance there are a number of sites—flat, level, of sufficient size to accommodate our long runways, but strategic location must be considered; therefore, we cannot build all our airfields there. Overseas, as well as Continental U. S. locations must be considered. Once a site is determined to be acceptable from a terrain standpoint, that is, the proper number of runways to satisfy wind coverage criteria can be laid out, then many other factors immediately become important. These include but are not limited to soil conditions, availability of utilities, accessibility by road, rail, cost of construction, cost of land, available housing in nearby communities, estimated community acceptance, distance from a sizeable community, degree of saturation of air space surrounding proposed site, climatology, availability of construction materials, availability of local labor. Site selection cannot be accomplished while sitting behind a desk in the Pentagon. It requires a complete team of experts who must go out in the field and gather the necessary facts first-hand. These engineers are generally

aided by topographic maps, climatological studies, census reports, aerial photographs and brochures prepared by interested community groups. However, every square foot of the site should be thoroughly tramped over on foot to verify existing information and develop additional data not available from previously prepared studies.

From the political and public relations standpoint, these initial site selection investigations are usually unpublicized. If information were to be published that the Air Force was seriously preparing plans for an air base in a stated location in the continental United States, speculators would immediately go to work inflating the value of the land. Townspeople would become upset about the adequacy of the public school systems, adequacy of family housing and shopping facilities, utility systems, etc. Based on rumor or fact, many thousands of dollars would change hands due to the imminence of the proposed plan. Some of this activity is good for the Air Force and some of it is bad. If the base should be located elsewhere, the people who lost money—speculatively or through honest endeavor to help—would be hurt. If the base were located at the surveyed location, the Government probably would have to pay inflated prices for land, labor, utilities and transportation. At any rate—if information is not released until plans are reasonably complete and real estate negotiations are underway, the interest of both the Government and the local population is protected.

In overseas areas, lack of suitable land areas, the security aspect and the base rights negotiations are much more important considerations in site selection than they are in the continental United States or possessions. Those of you who have visited foreign countries outside the western hemisphere are familiar with the scarcity of land, intensive agricultural use and high population densities. In these countries, every square foot of land that is worth any thing is cultivated by families who have owned this land for generations. The only land not under cultivation is worthless, hilly country or deserts unsuitable for airfield construction. Location of our strategic or tactical air bases in foreign countries within range of potential enemy bases is of vital interest to the enemy. However, the plans can be completed and construction well under way before information as to the exact location and nature of the base is available to the enemy if proper security precautions are exercised. Base rights negotiations can be carried on much more effectively between U. S. State Department personnel and officials of friendly foreign governments if wide spread information concerning future U. S. air base construction is guarded. In the past, cases have arisen where the complete air base development program in a friendly foreign nation would have been jeopardized had advanced information concerning the sites been published in local news media. Base rights negotiations are further complicated by the few suitable airfield sites located on available land. Taking land from citizens of the country and giving it to the U. S. Government for construction of an air base often causes serious adverse political pressures. Expert diplomatic maneuvers are usually required before all obstacles can be overcome and the final base rights agreements signed. The success or failure of an entire air base project can very easily rest with the ability and judgment of the U. S. State Department negotiators as well as the site selection engineers.

(b) Master Planning:—Let us now consider that the site selection team has completed its study, negotiations for the real estate have been successful and the new air base site has been accepted and included in the Air Force base utilization program. A basic and a long range mission are then assigned to the base. At this point, before any construction can begin, a complete master

plan for the base must be prepared. For this job, a qualified and experienced architect-engineer firm is hired by the Air Force to study the site and proceed with the preparation of the master plan. The architect-engineer will need certain information and data before arriving at the most logical plan of development. These data include real estate boundaries, topography, soil borings, meteorological data, proposed mission of the base, personnel strengths, types of aircraft, air-space requirements, regional highway and rail networks, aerial photographs and other information. Some of this information is available in published form, some will have to be developed by the architect-engineer. After analyzing all available information and verifying its accuracy, the architect-engineer prepares a series of documents known as the master plan. Upon approval by Headquarters, U. S. Air Force, this plan becomes the basis for all siting, construction and future development of the base. A good master plan will assure logical and economical development of the base from initial construction to ultimate development. It is worth its weight in gold. A poor master plan can cause much trouble and headaches. It will not be worth the paper it is written on and can cost the Government untold dollars in construction items that may later have to be removed.

(c) Programming:—Before Congress appropriates funds for any air base construction, Headquarters, U. S. Air Force must present a program of facilities needed. Generally this is a phased program which will build only an increment of the total master planned base. We may have a master plan for a huge base, perhaps large enough when completed to accomodate two wings of medium bombers, two squadrons of tankers, a numbered Air Force headquarters, fighter interceptor squadron and several other odds and ends. The first year's construction probably will provide only a small portion of the ultimate base mission. Nevertheless, the items constructed must mesh into the overall picture of the ultimate mission, yet be usable increments in themselves. For example, a hangar must be constructed so that it is completely usable; it must have an access apron, water, sewerage, power, heat. It must be located so that it is both economical and suitable from an operational standpoint. It should be neither too large nor too small for its immediate mission but still be sited so that any future expansion can be readily provided. These qualities inherent in this one item of construction must be kept intact in each item and in each increment or group of items built. In this way, the phased construction of the base will at all times be in perfect balance. With proper programming; usable increments, economy, and operational suitability of constructed items is assured.

(d) Design:—The next stage of development following programming is the design stage. From this point until the base is completed, the bulk of the work is handled by construction agencies outside the Air Force. Both design and construction are turned over to either the Corps of Engineers, U. S. Army, or Bureau of Yards and Docks, U. S. Navy for accomplishment. In a few special cases, Air Force commands handle this work. Assuming now that Congress has authorized construction of a base and appropriated funds for this purpose; we are ready, with the aid of the master plan and our definitive drawings, to start design. Upon receipt of a design directive from Headquarters, U. S. Air Force, the construction agent proceeds with the engineering design, working drawings and specifications. He places individual projects under contract with architect-engineer firms who grind out the working drawings and specifications. The Directorate of Installations, Headquarters United States Air Force, maintains close liaison with our construction agencies in the field through Air Force Installations Representatives who are located with the several Division

Engineer Offices. These representatives are actually field extension offices of the Directorate of Installations. They approve plans and specifications and monitor construction projects in their particular area which covers the same geographical area as the Division Engineer. Upon completion of the design stage for each individual project, invitations for bid are then sent to qualified contractors.

In faraway areas, special designs are the rule rather than the exception. In Okinawa, buildings must all be designed to withstand typhoon strength winds. In Alaska and other Arctic regions, high winds, extreme cold, perma frost conditions and isolation must all be considered in design and planning. Isolated bases must be complete cities in themselves. In desert regions, extreme heat is a problem. In tropical climates, such as Guam and the Philippines, frame construction will soon rot away. All these special climatic conditions call for special skill in management and execution of any construction program. As long as aircraft must fly in any latitude or longitude, there is a requirement for bases all over the globe.

It takes a coordinated team to develop an air base. Each member must work very closely with the other members—the site selectors with the master planners and programmers; the designers with the master planners, programmers and constructors. In this way, many problems are solved before they ever present themselves. A site selection engineer will eliminate 90% of the construction problems if he picks a good site.

Looking into the future, the air base development planner faces spectacular problems. Today, he can see the mistakes that have occurred in the past 20 years, and profit by them up to a certain point. Yet there are deficiencies in our bases today that were caused, not by poor planning 20 years ago but rather by technological developments in air power that could not have been forecast with sufficient accuracy to warrant a change in the air base planning concepts of that time. Similar technological advances in future aircraft, weapons, strategy and tactics will dictate changed air base requirements and planning concepts that are foreseeable today, but not identifiable.

Perhaps the most important concept relates to supersonic speeds in the movement of aircraft. Increased speed operates to compress the time within which the crews aloft and their support on the ground must accomplish their functions. The exact nature of this problem is subject to development, but it appears certain that our inventory of facilities will be substantially increased as to variety, dimensions, and quality. Another effect of increased speeds will probably see the elimination of stepping-stone type tactical bases for the support of ground armies. The World War II practice of support fields every 20 to 50 miles will give way to fewer and larger bases of that type, since the fighter-bomber can cover the great distances so much faster in relation to the movement of ground troops or surface vessels.

The fuel which will be burned in aircraft of the future is another unknown. Will it be a solid, liquid or gas? If nuclear fuel is used, will it be easy to handle or difficult? We know that at the present time research work is underway to develop nuclear-propelled ships and aircraft. Design and construction of the fuel storage and dispensing system will be a problem falling on the shoulders of the air base planning engineer. However, until much more information is forth coming from research organizations, about all the air base planner can do is provide suitable future locations for a highly sensitive aircraft fuel.

There must necessarily be engineering speculation as to types of passive defense measures which will be appropriate to the future. The striking power

of the Air Force depends upon four factors—men, planes, weapons and bases—all vulnerable to enemy attack, especially in overseas areas. Passive defense is very closely related to air base planning, and by applying recognized principles through new techniques, the survival of our forces will be increased and offensive missions facilitated. But the engineer cannot recommend hiding too well, lest he lose offensive capability. Reasonable protection to personnel already indicates masonry barracks and other housing, as is recommended for the civil population. In the final analysis, the answer will be the same as we are professionally used to producing—an engineering solution that is sound of application under the circumstances in effect at the time it is used.

Since the American construction industry can certainly produce any articles that the Air Force may require in terms of base construction, it is our very grave responsibility to keep base planning criteria at least abreast if not ahead of new requirements in aircraft and weapons and new concepts of air operations.

## PROCEEDINGS-SEPARATES

The technical papers published in the past year are presented below. Technical-division sponsorship is indicated by an abbreviation at the end of each Separate Number, the symbols referring to: Air Transport (AT), City Planning (CP), Construction (CO), Engineering Mechanics (EM), Highway (HW), Hydraulics (HY), Irrigation and Drainage (IR), Power (PO), Sanitary Engineering (SA), Soil Mechanics and Foundations (SM), Structural (ST), Surveying and Mapping (SU), and Waterways (WW) divisions. For titles and order coupons, refer to the appropriate issue of "Civil Engineering" or write for a cumulative price list.

### VOLUME 79 (1953)

JULY:[a] 200(SM)[b], 201(ST)[b], 202(EM)[b], 203(SM)[b], 204(AT)[b], 205(EM)[b], 206(ST)[b], 207(SA)[b], 208(SA)[b], 209(ST)[b], 210(SU)[b], 211(EM)[b], 212(SU)[b], 213(IR)[b], 214(HW)[b], 215(SM)[b], 216(ST)[b], 217(ST)[b], 218(ST)[b], 219(ST)[b], 220(SM)[b], 221(HW)[b], 222(SM)[b], 223(EM)[b], 224(EM)[b], 225(EM)[b], 226(CO)[b], 227(SM)[b], 228(SM)[b], 229(IR)[b].

AUGUST: 230(HY), 231(SA), 232(SA), 233(AT), 234(HW), 235(HW), 237(AT), 238(WW), 239(SA), 240(IR), 241(AT), 242(IR), 243(ST), 244(ST), 245(ST), 246(ST), 247(SA), 248(SA), 249(ST), 250(EM)[c], 251(ST), 252(SA), 253(AT), 254(HY), 255(AT), 256(ST), 257(SA), 258(EM), 259(WW).

SEPTEMBER: 260(AT), 261(EM), 262(SM), 263(ST), 264(WW), 265(ST), 266(ST), 267(SA), 268(CO), 269(CO), 270(CO), 271(SU), 272(SA), 273(PO), 274(HY), 275(WW), 276(HW), 277(SU), 278(SU), 279(SA), 280(IR), 281(EM), 282(SU), 283(SA), 284(SU), 285(CP), 286(EM), 287(EM), 288(SA), 289(CO).

OCTOBER:[d] 290(all Divs), 291(ST)[c], 292(EM)[c], 293(ST)[c], 294(PO)[c], 295(HY)[c], 296(EM)[c], 297(HY)[c], 298(ST)[c], 299(EM)[c], 300(EM)[c], 301(SA)[c], 302(SA)[c], 303(SA)[c], 304(CO)[c], 305(SU)[c], 306(ST)[c], 307(SA)[c], 308(PO)[c], 309(SA)[c], 310(SA)[c], 311(SM)[c], 312(SA)[c], 313(ST)[c], 314(SA)[c], 315(SM)[c], 316(AT), 317(AT), 318(WW), 319(IR), 320(HW).

NOVEMBER: 321(ST), 322(ST), 323(SM), 324(SM), 325(SM), 326(SM), 327(SM), 328(SM), 329(HW), 330(EM)[c], 331(EM)[c], 332(EM)[c], 333(EM)[e], 334(EM), 335(SA), 336(SA), 337(SA), 338(SA), 339(SA), 340(SA), 341(SA), 342(CO), 343(ST), 344(ST), 345(ST), 346(IR), 347(IR), 348(CO), 349(ST), 350(HW), 351(HW), 352(SA), 353(SU), 354(HY), 355(PO), 356(CO), 357(HW), 358(HY).

DECEMBER: 359(AT), 360(SM), 361(HY), 362(HY), 363(SM), 364(HY), 365(HY), 366(HY), 367(SU)[e], 368(WW)[e], 369(IR), 370(AT)[e], 371(SM)[e], 372(CO)[e], 373(ST)[e], 374(EM)[e], 375(EM), 376(EM), 377(SA)[e], 378(PO)[e].

### VOLUME 80 (1954)

JANUARY: 379(SM)[e], 380(HY), 381(HY), 382(HY), 383(HY), 384(HY)[e], 385(SM), 386(SM), 387(EM), 388(SA), 389(SU)[e], 390(HY), 391(IR)[e], 392(SA), 393(SU), 394(AT), 395(SA)[e], 396(EM)[e], 397(ST)[e].

FEBRUARY: 398(IR)[f], 399(SA)[f], 400(CO)[f], 401(SM)[e], 402(AT)[f], 403(AT)[f], 404(IR)[f], 405(PO)[f], 406(AT)[f], 407(SU)[f], 408(SU)[f], 409(WW)[f], 410(AT)[f], 411(SA)[f], 412(PO)[f], 413(HY)[f].

MARCH: 414(WW)[f], 415(SU)[f], 416(SM)[f], 417(SM)[f], 418(AT)[f], 419(SA)[f], 420(SA)[f], 421(AT)[f], 422(SA)[f], 423(CP)[f], 424(AT)[f], 425(SM)[f], 426(IR)[f], 427(WW)[f].

APRIL: 428(HY)[e], 429(EM)[e], 430(ST), 431(HY), 432(HY), 433(HY), 434(ST).

MAY: 435(SM), 436(CP)[e], 437(HY)[e], 438(HY), 439(HY), 440(ST), 441(ST), 442(SA), 443(SA).

JUNE: 444(SM)[g], 445(SM)[g], 446(ST)[g], 447(ST)[g], 448(ST)[g], 449(ST)[g], 450(ST)[g], 451(ST)[g], 452(SA)[g], 453(SA)[g], 454(SA)[g], 455(SA)[g], 456(SM)[g].

JULY: 457(AT), 458(AT), 459(AT)[e], 460(IR), 461(IR), 462(IR), 463(IR)[e], 464(PO), 465(PO)[e].

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a. Beginning with "Proceedings-Separate No. 200," published in July, 1953, the papers were printed by the photo-offset method.
b. Presented at the Miami Beach (Fla.) Convention of the Society in June, 1953.
c. Presented at the New York (N.Y.) Convention of the Society in October, 1953.
d. Beginning with "Proceedings-Separate No. 290," published in October, 1953, an automatic distribution of papers was inaugurated, as outlined in "Civil Engineering," June, 1953, page 66.
e. Discussion of several papers, grouped by divisions.
f. Presented at the Atlanta (Ga.) Convention of the Society in February, 1954.
g. Presented at the Atlantic City (N.J.) Convention in June, 1954.

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